Evaluation of Lead Exposure at an Indoor Law Enforcement Firing Range

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Contents

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The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation. Photo by NIOSH.

Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from the employer at a federal law enforcement indoor firing range. The employer was concerned about lead exposure among firearms instructors. We evaluated the firing range in December 2016 during a weapons qualification course.

What We Did

- We observed work practices, including shooting, cleaning firearms, range hygiene, and range cleanup.
- We measured instructors' and shooters' airborne exposures to lead.
- We determined lead, copper, and zinc concentrations on surfaces inside and outside the range.
- We determined whether instructors had lead contamination on their hands and footwear when they left the range.
- We evaluated ventilation system performance.
- We interviewed all four firearms instructors about work history and practices, lead-related medical history, and recreational lead exposure sources.
- We reviewed instructors' previous blood lead level test results.
- We collected venous blood samples from instructors to measure current blood lead levels.

We evaluated lead exposures in an indoor law enforcement firing range. We found lead in the air, but below occupational exposure limits. We also found lead on all surfaces tested including instructors' skin and footwear. All instructors had detectable blood lead levels. We recommended testing and balancing the ventilation system, improving hand hygiene, and starting a lead exposure monitoring program.

What We Found

- Air sampling results for lead were below occupational exposure limits.
- We found lead and copper on all tested surfaces. We found zinc on most tested surfaces.
- Instructors had lead on their hands and footwear as they left work to go home.
- All instructors wore their work clothes and shoes home. This potentially exposes family members to lead.
- Instructors and shooters used dry sweeping methods to remove lead-dust and lead-dust contaminated objects from in front of the firing line at the end of the day.
- The ventilation system was not performing according to guidelines from the National Institute for Occupational Safety and Health.
- The venous blood samples we collected showed that instructors had blood lead levels between 3.4 and 11 micrograms per deciliter. Levels above 5 micrograms per deciliter are considered elevated.

What the Employer Can Do

- Hire a firing range ventilation specialist for all range ventilation maintenance. Test and balance the system.
- Implement and manage a lead safety program that follows the Occupational Safety and Health Administration lead standard [29 CFR 1910.1025].
- Keep and maintain Occupational Safety and Health Administration injury and illness logs.
- Remove all materials being stored in firing lanes because they disrupt airflow in the range.
- Repair the target retrieval system.
- Have employees use wet cleaning methods and avoid dry sweeping debris, casings, and lead dust from the floor of the range.
- Provide instructors with clothes and shoes to wear only at work, no-slip style disposable shoe covers, two lockers to separate street clothes from work clothes, and on-site laundry service to prevent take-home exposures.

What Employees Can Do

- Do not dry sweep debris, casings, and lead dust from the floor of the range. Continue to use the bullet casing sweeper.
- Use a lead-removal cleaning solution for all surface cleaning activities.
- Enter and exit the range through the appropriate entry or exit door.
- To avoid tracking lead dust out of the range and possibly into your home:
    - Use no-slip style disposable shoe covers and dedicated work shoes
    - Use dedicated work clothes and shoes kept in a locker at the workplace and laundered either on-site or by a lead-certified laundry service.
- Wash hands with lead-removal soap each time you leave the range. Wash hands with regular soap and water before eating while at work.

Abbreviations

μg/m^3	Micrograms per cubic meter
μg/dL	Micrograms per deciliter
ACGIH®	American Conference of Governmental Industrial Hygienists
AHU	Air handling unit
BLL	Blood lead level
cfm	Cubic feet per minute
CFR	Code of Federal Regulations
FOH	Federal Occupational Health
LOD	Limit of detection
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
REL	Recommended exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average

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Introduction

The Health Hazard Evaluation Program received a request from the employer at a federal law enforcement indoor firing range in Washington, DC. The employer was concerned about lead exposure to firearms instructors. We visited the building in December 2016 to interview instructors and assess their exposure to lead, copper, and zinc. In December 2016, we sent a letter to instructor and employer representatives outlining our preliminary findings and recommendations. In January 2017, we provided a summary of the environmental sampling and blood lead results to the employer and instructor representatives. Personal sampling results were sent to each instructor and shooter who participated in the evaluation.

Range Description

Law enforcement officers performed their semiannual qualifying shoots in this indoor firing range to maintain their sidearm weapons certification. The range was staffed by four full-time instructors who oversaw the certification of approximately 400 officers. Instructors typically work 10-hour shifts. Although this range hired a safety officer in 2015, it did not have a comprehensive lead safety program in place. During our visit, instructors split their time between the classroom, office, and firing range. Typically, one instructor oversaw the weapon cleaning and maintenance training just outside of the range area (Figure 1). During shooting, three instructors stood on the range behind the shooters. One instructor remained in the range observation booth, also known as the tower, providing instructions to the shooters. This range used frangible and nonfrangible (duty) ammunition. Frangible ammunition is designed to disintegrate on impact to minimize penetration into the target whereas duty ammunition is designed to remain intact to maximize target penetration. Duty ammunition contained mostly lead, while frangible bullets contained mostly copper and some zinc.

The range had 14 firing lanes and a dedicated ventilation system (Figure 1). The range ventilation system is described in the results and discussion section. The weapons cleaning area is adjacent to the range and is supplied by a separate ventilation system that also serves the main building. The break room and office areas for instructors are in a separate part of the building and are also supplied by the main building ventilation system.

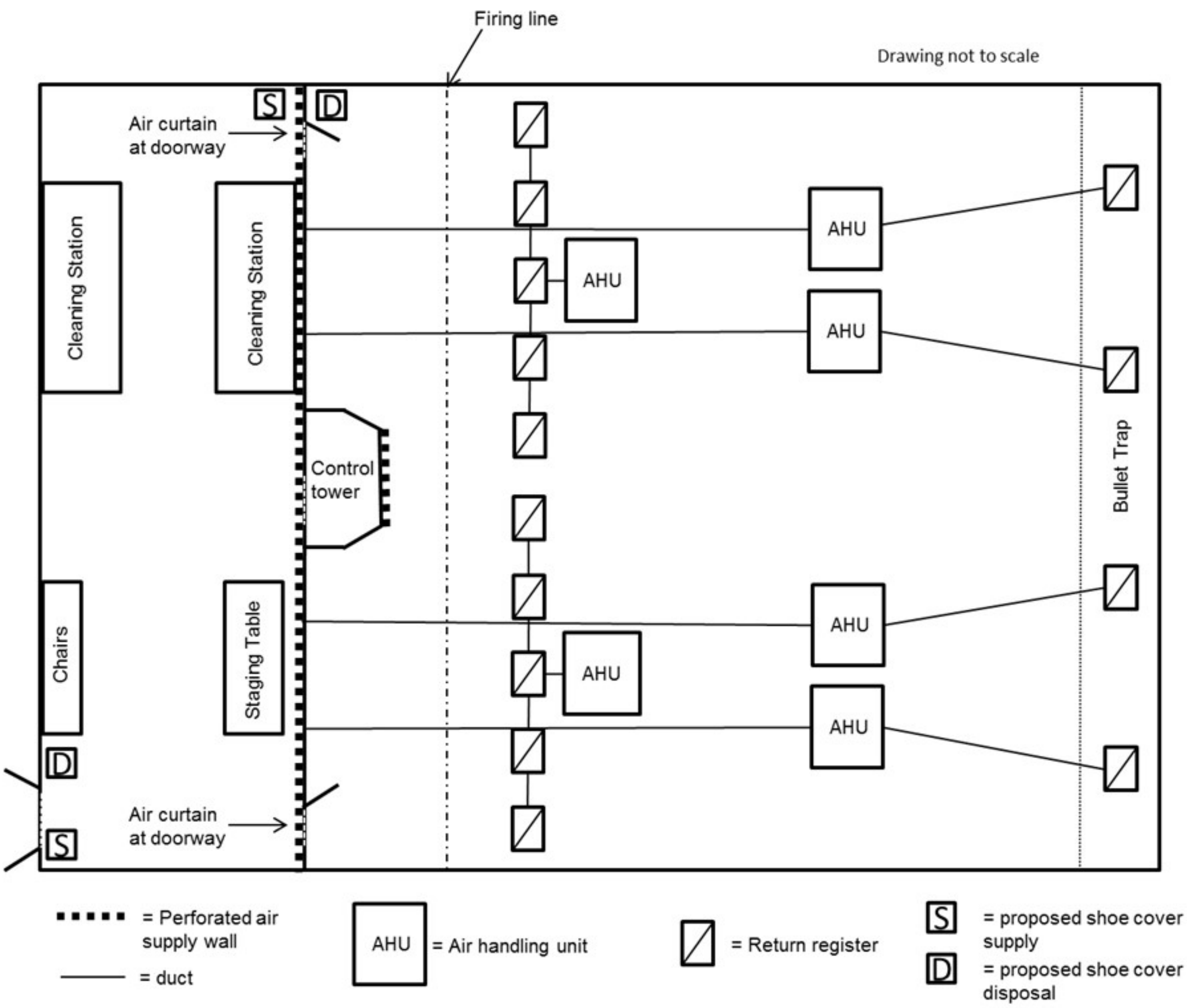

Figure 1. Layout of the firing range and weapons cleaning area.

Methods

The objective of this evaluation was to determine if the firearms instructors were exposed to lead above recommended levels and if this was evidenced by elevated blood lead levels (BLLs). To achieve this objective, we (1) measured instructor and shooter airborne lead concentrations during weapons qualification; (2) determined the lead concentrations on surfaces inside and outside of the range; (3) determined whether instructors had lead contamination on their hands and footwear when leaving the range; (4) evaluated the ventilation system performance as it relates to National Institute for Occupational Safety and Health (NIOSH) guidelines; (5) determined work practices could increase instructors' lead exposure; and (6) measured current blood lead levels.

During our visit, we observed work practices during a weapons qualification course, including shooting, cleaning firearms, range hygiene, and range cleanup. We collected personal air samples from four instructors and five shooters over 1 day. Each sample was analyzed for lead, copper, and zinc according to NIOSH Method 7303 [NIOSH 2017].

We collected surface wipe samples for lead, copper, and zinc in the range, offices, and breakroom using premoistened Palintest® Dust Wipes according to NIOSH Method 9102 [NIOSH 2017]. We used a disposable template to collect each wipe sample over an area of 100 square centimeters. Hand wipe samples were collected on the four instructors prior to leaving work for the day. We had the instructor wipe the palm and back surfaces of each hand for a total of 30 seconds. We collected footwear sole wipe samples on the four instructors prior to leaving the range area for the day, after walking across the adhesive mat leaving the range. We had instructors wipe the sole of one shoe for 30 seconds. Hand and footwear sole wipe samples were evaluated using a Full Disclosure® qualitative colorimetric screening method for the presence of lead.

We reviewed blueprints and inspected the range ventilation system including the air handling units (AHUs) and ductwork (Figure 1). We also inspected the exhaust outlets from the roof of the range. We used qualitative and quantitative methods to characterize the airflow in and around the firing range. We also checked airflow direction at each doorway leading to and from the range to determine whether the range was under positive or negative pressure relative to the cleaning and preparation area. We used ventilation smoke (Degree Controls, Inc.) to visualize airflow patterns within the range. We also used an electronic micromanometer (Shortridge Instruments, Inc. AirData Multimeter Model ADM-860C) to measure air velocity. We focused on the following locations: (1) the perforated air supply wall; (2) just behind the firing line at each shooting stall; (3) approximately 15 feet downrange at the close quarters combat firing line; (4) approximately halfway downrange; and (5) at the front of the bullet trap.

All four instructors were invited to participate in blood lead testing and confidential medical interviews. The interviews covered work tasks and practices, possible sources of recreational lead exposure, and lead-poisoning related symptoms. Venous blood samples were drawn to measure lead levels; these results are the basis for the information presented below in Results and Discussion. We also performed a finger stick to measure the levels of lead with a portable blood-lead testing device so that we could examine its utility compared to venous blood sampling for lead. Results of the finger stick testing are in Appendix C.

We reviewed BLLs on the four instructors from tests conducted by the Federal Occupational Health (FOH) clinic in July 2016. We also reviewed current lead-related training materials. The site did not maintain Occupational Safety and Health Administration (OSHA) Forms 300 Log of Work-Related Injuries and Illnesses. We also reviewed all lead training materials given to instructors.

Results and Discussion

Workplace Observations

During our visit, shooters were engaged in a 9-mm handgun qualification exercise. The exercise consisted of classroom activities, firearm cleaning, and target shooting. Each shooter fired a total of 594 rounds. Of the 594 rounds fired, 418 (70%) were copper frangible ammunition, and 176 (30%) were duty ammunition.

Required personal protective equipment worn during qualification for both shooters and instructors consisted of ear plugs and earmuffs (double hearing protection) and safety glasses. Instructors wore duty uniforms. Shooters wore duty uniforms or off duty clothes if they came in outside of a work shift. Instructors and shooters had access to a locker room with shower facilities, but instructors reported that they did not use it. An adhesive floor mat at the exit of the range was meant to clean the bottom of footwear when people left the range. We noticed the mat needed to be changed multiple times per day and appeared to lose effectiveness quickly because of buildup from foot traffic in and out of the range (Figure 2).

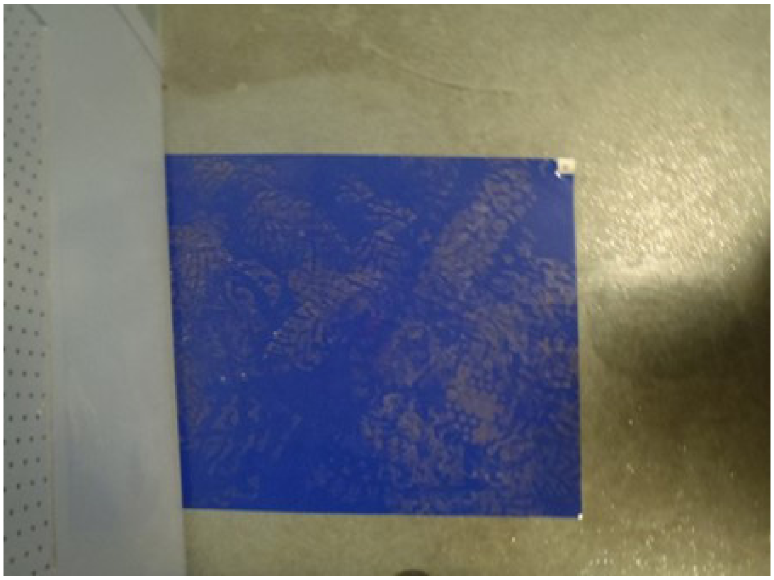

Figure 2. Adhesive floor mat at range exit door used to remove footwear contamination. The mat is covered with footprints. Photo by NIOSH.

At the time of our visit, the target retrieval system was broken. The target retrieval system was an automatic pulley system that shooters use to place the targets downrange and to bring the targets back to the firing line. The controls for this system were located at the firing line. Because the retrieval system was broken, shooters and instructors had to go into the contaminated area downrange from the firing line, which could add to their exposure to lead dust through skin contact and dermal absorption. At different times during the qualification exercises, we observed shooters walking downrange, pushing the target hangers with their bare hands, and moving them downrange (Figure 3). Neither shooters nor instructors wore gloves during these tasks.

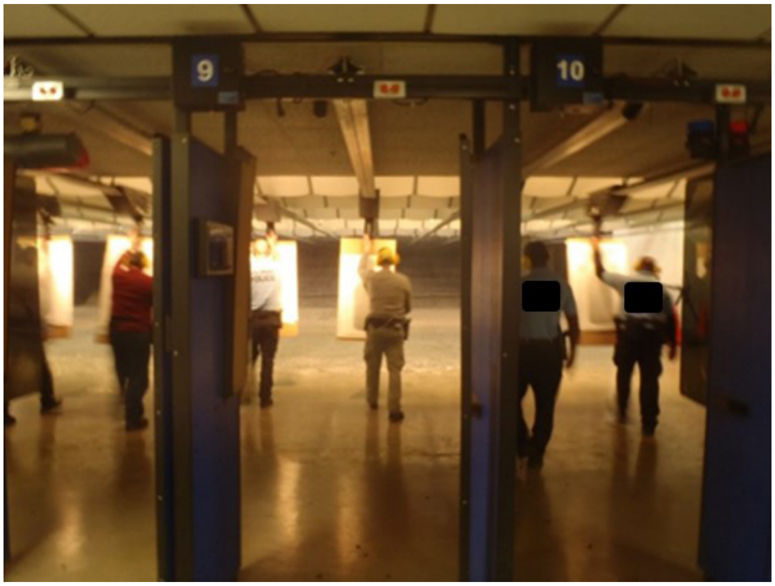

Figure 3. Shooters moving the target retriever downrange by hand. Photo by NIOSH.

Instructors reported that lanes 1, 2, and 12–14 were not used. We observed that lanes 1–3 and 12–14 were not used during qualification exercises. We observed material being stored in these unused lanes (Figure 4). Two pedestal fans were placed on each side of the range in lanes 1 and 14. Instructors reported that they used these fans during warmer weather because the range did not have air conditioning.

Figure 4. Material being stored in the shooting lanes of the range. Photo by NIOSH.

We observed shooters and instructors dry sweeping the range with brooms (Figure 5). Debris from the floor was swept onto a dust pan and dumped into a bucket at the end of the work day. We also observed instructors using a bullet casing sweeper (Figure 6). Casings were collected between shooting exercises and at the end of the day using the bullet casing sweeper and dumped into a bucket near the control tower for disposal. No gloves or respiratory protection were worn by instructors or shooters during cleaning activities. The bullet trap collected rounds and used a conveyor system to deposit rounds into a drum outside of the building (Figure 7). Instructors reported that a contractor periodically collected the contents of this drum.

Figure 5. Instructors and shooters dry sweeping the floor with brooms downrange from the firing line at the end of the day. Photo by NIOSH.

Figure 6. Bullet casing sweeper stored on the range behind the firing line in lane one. Photo by NIOSH.

Figure 7. Drum outside the building used to collect spent rounds fired into the bullet trap. Photo by NIOSH.

Air Sampling

We took nine personal air samples for lead, copper, and zinc. Full-shift personal air samples were collected on four instructors. Task-based personal air samples were collected on five shooters while they were shooting and cleaning weapons at the range.

Table 1 presents the personal air sampling results for lead, copper, and zinc. The instructors' full-shift personal air samples for lead ranged from 5.2 to 13 micrograms per cubic meter of air ($\mu g/m^3$). These samples were below the OSHA, NIOSH, and American Conference of Governmental Industrial Hygienists (ACGIH®) occupational exposure limit (OEL) of 50 $\mu g/m^3$. The five shooters' task-based personal air samples for lead ranged from 28 to 46 $\mu g/m^3$. The task-based results cannot be compared to the full-shift OELs but suggest that shooters could exceed the OEL for lead if they worked longer hours under similar conditions.

The instructors' full-shift personal air samples for copper ranged from 9.8 to 35 $\mu g/m^3$. Shooters' task-based personal air samples for copper ranged from 47 to 86 $\mu g/m^3$. The particulate likely contains a mix of particles of varying sizes including inhalable, respirable, and metal fume particles. All full-shift samples were below the OSHA, NIOSH, and ACGIH OEL of 1,000 $\mu g/m^3$ for copper dust. All full-shift samples were also below the OSHA and NIOSH OEL of 100 $\mu g/m^3$, and ACGIH OEL of 200 $\mu g/m^3$ for copper fume. The task-based results cannot be compared to the full-shift OELs but suggest that shooters would not exceed the OEL for copper if they worked longer hours under similar conditions.

The instructors' full-shift personal air samples for zinc ranged from not detected to 4.5 µg/m^3. Shooters' task-based personal air samples for total zinc ranged from 0.32 to 0.63 µg/m^3. All samples were well below the lowest OEL of 2,000 µg/m^3 for respirable zinc oxide particulate (Table 1). The task-based results cannot be compared to the full-shift OELs but suggest that shooters would not exceed the OEL for zinc if they worked longer hours under similar conditions.

Table 1. Personal air sampling results for lead, copper, and zinc (µg/m^3)

Job title	Sample duration (minutes)	Lead concentration	Copper concentration	Zinc concentration*
Instructor	520	13	35	4.5
Instructor	520	5.2	19	[0.13]
Instructor	518	9.8	9.8	Not Detected
Instructor	520	7.0	15	[0.17]
Shooter	364	29	47	[0.33]
Shooter	363	43	84	0.63
Shooter	360	28	62	[0.32]
Shooter	354	46	86	0.56
Shooter	354	39	76	0.50
OSHA PEL		50	1,000 (dust) 100 (fume)	5,000 (zinc oxide fume or respirable dust)
NIOSH REL		50	1,000 (dust) 100 (fume)	5,000 (zinc oxide fume or total dust)
ACGIH TLV		50	1,000 (dust) 200 (fume)	2,000 (zinc oxide fume or respirable dust)

PEL= Permissible exposure limit

REL = Recommended exposure limit

TLV = Threshold limit value

*The minimum detectable concentration for zinc was 0.1 µg/m^3 for instructors and shooters. The minimum quantifiable concentration for zinc was 0.29 µg/m^3 for instructors and 0.42 µg/m^3 for shooters.

[ ] = Estimated concentration; this concentration was between the minimum detectable concentration and minimum quantifiable concentrations.

Surface Sampling

Table 2 presents the surface sampling results for lead, copper, and zinc. We detected lead and copper on all sampled surfaces throughout the building. The target hanger, which is always handled without gloves, had the highest level besides the floor samples. We detected zinc on all sampled surfaces except the microwave. The presence of contamination on top of the cubicle divider in the office area indicates that lead, copper, and zinc were being transferred from the range into the main building.

Table 2. Surface wipe sample results for lead, copper, and zinc (micrograms per 100 square centimeters)

Sample location	Lead concentration	Copper concentration	Zinc concentration
Break room			
Keypad and handle of the microwave*	[0.72]	1.2	Not detected
Refrigerator handle*	12	27	220
Instructor office area			
Top of cubicle divider in office area*	1,000	700	540
Range area			
Floor, hallway outside the door to the staging area	150	220	47
Table, weapon cleaning area	66	160	47
Floor, weapon cleaning area near exit door	2,000	3,000	110
Desk top, viewing area	60	60	9.9
Lane 10 barricade handle*	530	390	57
Ammunition loading bench top	470	430	16
Lane 9 target hanger*	1,800	590	61
Floor, range, in front of sticky mat	4,100	6,700	190
Floor, lane 9, 10 feet downrange from shooting stall	1,800	4,100	130
Minimum detectable concentration	0.2	0.1	2.0
Minimum quantifiable concentration	0.77	0.24	7.3

*Estimated 100 square centimeters. The disposable templates were not compatible with the shape of the surface.

[ ] = Estimated concentration; this concentration was between the minimum detectable and minimum quantifiable concentrations.

We found lead on the hands of the four instructors after they left the range area for the day. All colorimetric tests were positive; the limit of detection is 18 micrograms of lead per wipe. All instructors reported washing their hands with regular soap and water multiple times that day, but never with the lead removal soap or wipes. No instructors had washed their hands immediately prior to our sample collection. Lead was also present on the soles of the instructors' footwear after leaving the range area for the day. Lead dust can contaminate surfaces and be transferred onto an instructor's hands, and then be transferred from their hands to their mouth. Any lead dust on hair, skin, clothes, or shoes may be transferred to surfaces inside personal vehicles, homes, and to other family members who come into contact with contaminated surfaces.

Ventilation System Evaluation

We accessed the ventilation system from the catwalk above the range. We located all air supply and exhaust ducts. Outdoor air enters the system through two 36-inch by 36-inch inlets. Supply air is delivered to the perforated air supply wall by twelve 26-inch by 8-inch ducts using four individually controlled AHUs. According to blueprints, the system is designed to deliver a total of 12,000 cubic feet per minute of air (cfm). The perforated air supply wall is approximately 10 feet behind the firing line and is designed to direct air in a uniform manner toward the firing line and downrange past the shooter (Figure 1).

Approximately 10 feet downrange, 10 exhaust grilles approximately 6 inches by 70 inches in size, are located approximately 15 feet above the floor (Figure 8). These grilles exhaust air to the outdoors through four 24-inch by 18-inch ducts designed to exhaust 1,000 cfm each, using two individually controlled AHUs. Four 30-inch by 24-inch grilles are further downrange, at the bullet trap. Each is designed to return 2,000 cfm of air to the AHU. This return air, along with outdoor air from the outdoor air intakes, supplies the makeup air to the perforated air supply wall. All AHUs filter the air using a three-stage filter arrangement. The first stage contains a minimum efficiency reporting value 11 filter, the second stage contains a minimum efficiency reporting value 12 filter, and the third stage contains a high efficiency particulate air filter. The employer reported that the filters are replaced by the cleaning contractor. Stage one is replaced monthly, stage two is replaced every 6 months, and stage three is replaced annually.

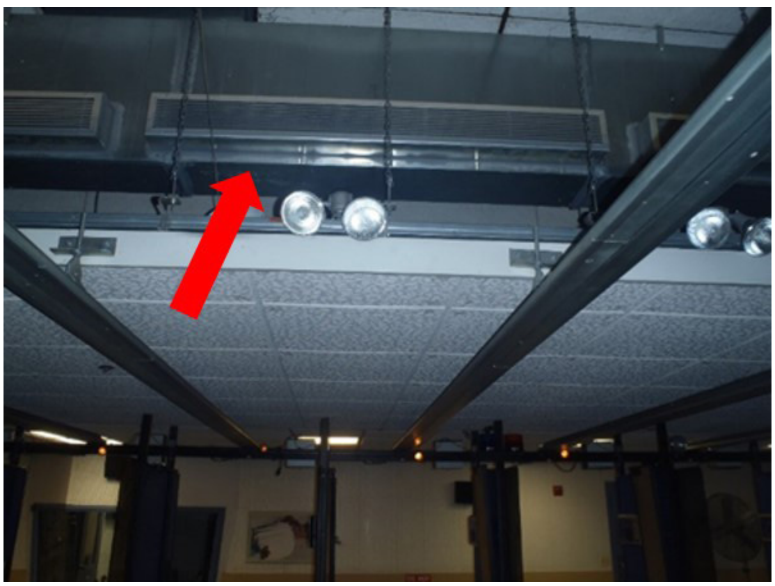

Figure 8. Exhaust grilles above the floor approximately 10 feet downrange from the firing line. Photo by NIOSH.

All six of the three-stage filter banks are monitored for pressure drop across the filter arrangement. Gauges in the control tower show the pressure drop and monitors also have pre-alarm and final alarm indicators. The pre-alarm is an amber light indicating that filters need to be changed soon. The final alarm is a red light indicating that the filters need to be changed immediately. The final alarm shuts down all of the AHUs.

Achieving the correct balance between air supply and exhaust is important in limiting the risk of lead and copper exposures resulting from firing range use. Firing ranges should be under slight negative pressure relative to adjacent areas to minimize migration of air contaminants to other areas within the building. The air curtains at both doors between the range and the weapons cleaning area (Figure 1) are designed to limit contaminants from moving into the weapons cleaning area by allowing the supply air to move across the entrance and exit doors. Smoke tests at these doors revealed air moving away from the air curtains and moving downrange. This suggests that the air curtains were effectively operating as designed. Figure A1 in Appendix A shows airflow patterns and velocities inside the firing range. We found that the velocities in many lanes were low relative to NIOSH recommendations [NIOSH 2009]. NIOSH recommends that all air supplied to the range be distributed evenly across all areas of the range to prevent areas of turbulence. Air velocity at the firing line should be between 50 and 75 feet per minute. Air velocity downrange past the firing line should be a minimum of 30 feet per minute in each lane and should be evenly distributed. Based on these recommendations, only lanes 7 and 11 had acceptable firing line velocities. Air velocities downrange from the firing line were not uniform and many were measured to be less than 30 feet per minute. Results of the smoke test further supported the finding that the velocities in many lanes were low relative to NIOSH recommendations (Appendix A, Figure A1). The arrows in Figure A1 show the direction of airflow that was visualized with the smoke machine. Air moved from the perforated air supply wall towards the firing line but at the firing line we observed areas of turbulence around the shooting stalls. Approximately halfway downrange we observed that the air slowly mixed but was hardly moving downrange at all. At the bullet trap we observed very little air movement. We also noticed a note on the control panel stating "exhaust #1 not working" which is consistent with our findings showing a reduction or lack of air movement on the right side of the range (Figure 9).

Figure 9. Note taped to the control panel for the ventilation system stating "exhaust #1 not working." Photo by NIOSH.

Review of Current Lead-related Training Materials

Initial training on lead health hazards is covered in approximately 2 hours of the 10-day firearms instructor training program [FLETC 2015]. The training covers current OSHA standards for lead, exposure routes, health effects of lead in adults and children, and proper work practices. It was reported that all personnel using the range are required to sign a one-page document each year that reviews safe range behavior. This document does not cover lead hazards. No lead hazard refresher training is currently in place for instructors or shooters.

Medical Interviews and Blood Lead Level Testing

All four instructors participated in confidential medical interviews and BLL testing during the December 2016 site visit. The median duration of employment as an instructor at this range was 12 years (range: 6–18 years). Instructors reported that they spend 2–6 hours on average on the range each workday. None of the instructors reported ever requiring medical treatment for lead poisoning.

All four instructors had detectable BLLs that ranged between 3.4–11 micrograms per deciliter (µg/dL), with two above the current NIOSH surveillance case definition that defines a lead level ≥ 5 µg/dL as elevated (Appendix B) [NIOSH 2015]. All four instructors had at least one previous BLL test by the local FOH clinic in July 2016. At that time, all four had BLLs ≥ 5 µg/dL (range 6–25 µg/dL). Each instructor's December 2016 BLL was lower than their July 2016 level.

Although there were elements of a lead monitoring program in place, it did not appear to be part of a comprehensive program as mandated by OSHA. Instructors appeared to request BLLs at their own discretion depending on their perceived level of lead exposure risk. Instructors had their BLLs done through the local FOH clinic. These results were reviewed by an FOH physician and reported back to the individual. There was no formal communication back to the employer notifying them of elevated lead levels and the need to take any action.

The range was not cleaned in December 2015 as scheduled because the cleaning contractor had gone out of business. As a result, instructors began doing more of the range cleaning activities. The range safety officer reported that requests were made to evaluate whether the system was operating effectively. The requests were addressed by a heating, ventilation, and air-conditioning technician and not by a company with experience with maintaining firing range ventilation systems. Performing more range cleaning duties and overall impression of an ineffective range ventilation system, led to the perception of increased lead exposure risk. This prompted the two instructors with BLLs > 10 µg/dL at the December 2015 testing to have their BLLs rechecked in April 2016. The April 2016 BLLs for these two instructors were 25 and 26 µg/dL. The two instructors removed themselves from the range for 2 months. They returned after their BLLs had dropped to 14 µg/dL in July 2016. The decision to return to work was made by the instructors themselves. The physicians reviewing the BLL results did not communicate their findings with the employer.

All instructors were asked about ways to improve training about workplace lead exposures. Three of the instructors mentioned annual refresher training on lead. They reported not having reviewed lead safety since their initial instructor certification class.

Our interviews indicated that workplace programs and practices, including dry sweeping the floor, inconsistent use of lead removal soap for handwashing, and dry wiping range table surfaces, could contribute to increased lead exposure. We observed all of these practices during our visit. All instructors reported that lead removal soap was available in the range but use was inconsistent. All instructors reported having engaged in some type of range cleaning activity in the previous 3 months, ranging from daily to once a month in frequency. All instructors reported cleaning the downrange area, and three reported cleaning the gun cleaning tables, dry sweeping the range floor, and collecting casings for disposal. Some instructors reported cleaning tables using wet methods; glove use practices were inconsistent. It was mentioned that the target retrieval system needed to be repaired so instructors would not have to move the targets manually.

We asked about practices that could expose household members to lead carried home from the workplace (also known as take-home lead). None of the instructors reported having dedicated work clothes or shoes, using no-slip style disposable shoe covers, or showering before leaving the building at the end of a shift. Three instructors stated they never showered when arriving home from work, while one stated they always did. Three instructors reported they always changed out of their work clothes when arriving home, while one responded "sometimes" to this question. Only one instructor reported household members having their BLL measured since the instructor started work at this building. This instructor reported that no household members had a detectable BLL. Three instructors reported that their initial instructor training regarding workplace lead hazards was adequate but that there is no formal refresher training for lead hazards. One instructor commented that they did not feel that lead exposure was a significant health issue. A detailed discussion of lead's health effects and the dangers of take-home lead to household members is available in Appendix B.

We also asked about possible non-occupational sources of lead exposure. One instructor reported engaging in recreational shooting about once a month and remodeling a home built prior to 1978 (the U.S. Consumer Product Safety Commission banned lead-based paints from use in residential housing that year). No other instructors reported other non-work related sources of lead exposure. Some examples of these activities include collecting lead material for recycling, making their own leaded fishing lures, fueling aircraft that use leaded aviation gasoline, making pottery or other ceramics that use a lead-containing glaze, doing their own auto body work or handling car batteries, or working at another firing range either as paid employee or volunteer.

Adverse health effects associated with elevated lead levels include high blood pressure and decreased kidney function [NTP 2012]. Although two instructors reported high blood pressure, which can occur at a BLL < 10 µg/dL, none reported other possible lead-related health effects. Decreased kidney function, anemia, severe unexplained abdominal pain, or infertility issues tend to occur at much higher BLLs.

Just before our December 2016 visit, a safety officer was hired to oversee the lead exposure monitoring program, find a new range cleaning contractor, and maintain the OSHA injury and illness logs. A new range cleaning contractor had been hired but had not yet performed its first service at the time of our site visit. This may explain the lead contamination we found on surfaces throughout the range. Work practices like dry sweeping, infrequent handwashing, and a lack of disposable shoe covers may have contributed to contamination throughout the building.

Conclusions

A health hazard from exposure to lead exists in this firing range to all personnel who use this range. At risk personnel include instructors who work on the range each work day along with officers who visit the range quarterly for their required qualification shoots. All four instructors had detectable BLLs with two > 5 µg/dL, which NIOSH defines as elevated. Lead was detected on surfaces throughout the building, in the breathing zone of instructors and shooters, and also on instructors' hands and footwear as they left work to go home. A combination of ventilation system issues, insufficient range cleaning services, poor handwashing practices, and the lack of a comprehensive lead exposure monitoring program may have contributed to detectable BLLs among instructors. The ventilation system was not performing according to NIOSH recommendations. Lack of dedicated work clothes and shoes, use of available shower facilities, and on-site laundry service also increased the risk of take-home lead. Although adhesive floor mats are present, they must be used in combination with other methods to reduce the risk of take-home lead and contamination throughout the building.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage forming a labor-employer health and safety committee or working group to discuss our recommendations and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at this indoor law enforcement firing range.

Our recommendations are based on an approach known as the hierarchy of controls (Appendix B). This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and personal protective equipment may be needed.

Engineering Controls

Engineering controls reduce employees' exposures by removing the hazard from the process or by placing a barrier between the hazard and the employee. Engineering controls protect employees effectively without placing primary responsibility of implementation on the employee.

1. Consult a ventilation engineer with experience in designing firing range systems to repair or modify the ventilation system. The system should supply conditioned air to the range according to NIOSH specifications. The NIOSH website has useful information about firing range ventilation at http://www.cdc.gov/niosh/topics/ranges/.
2. Conduct a test and balance evaluation of the system after it is repaired or modified. Perform a smoke test to visualize airflow patterns and the direction of air movement.
    a. All air supplied to the range should be distributed evenly across all areas of the range to prevent areas of turbulence.

b. Air velocity at the firing line should be between 50 and 75 feet per minute.
c. Air velocity downrange past the firing line should be a minimum of 30 feet per minute in each lane and should be evenly distributed.
d. The ventilation system should exhaust more air than it supplies (about 10%).

3. Make sure the ventilation system is operating whenever the range is used or being cleaned.
4. Inspect the walls between the range and the adjacent office area. Seal any holes, gaps, or cracks that could allow lead-contaminated air to migrate from the range to other parts of the building.
5. Repair the target-retrieval system so that personnel no longer have to walk through a contaminated area to change and move targets.

Administrative Controls

The term administrative controls refers to employer-dictated work practices and policies to reduce or prevent hazardous exposures. Their effectiveness depends on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that policies and procedures are followed consistently.

1. Institute a lead exposure monitoring program according to the OSHA lead standard [29 CFR 1910.1025]. This standard provides requirements for engineering controls, exposure monitoring, work practices, housekeeping, and personal protective equipment to reduce occupational exposures to lead. Follow the medical surveillance program outlined in Appendix B in addition to all requirements of the OSHA standard.
2. Enter and exit the range through the appropriate entry or exit door. This will prevent tracking contamination from the range into the weapons cleaning and staging areas.
3. Require each instructor or shooter to wash hands with lead removal soap each time they leave the range.
4. Use lead removal soap prior to the use of any abrasive hand cleaner. Make sure employees are aware that abrasive cleaners can remove the outer layer of skin and could increase lead absorption.
5. Stop dry sweeping and only use either a wet method (a lead removal solution at the manufacturer's suggested concentration) or a high efficiency particulate air filtered vacuum, followed by a wet cleaning, to clean potentially contaminated surfaces.
    a. Brooms should never be used, even with dust suppression compounds.
    b. The specialized bullet casing sweeper should be the only dry method used to collect casings from the floor.
    c. Use a wet floor scrubber to clean downrange from the firing line at the end of the day.
6. Do not store materials in the firing lanes or operate pedestal fans in the range because they can disrupt airflow and affect the ability of lead particulate to move downrange. All air movement in the range should be uniform and directed downrange toward the bullet trap. When the ventilation system has been repaired it should supply conditioned air to the range and pedestal fans will no longer be needed.

7. Institute annual lead hazards refresher training.
8. Reduce risk of take-home lead and cross-contamination in the building by providing instructors with dedicated work clothes and shoes, separate lockers for street clothes and work clothes, and on-site laundry (or contract a laundry service qualified to handle lead-contaminated garments). Display the OSHA Quick Card on Take-home Lead Prevention in a highly visible location (available at https://www.osha.gov/Publications/OSHA3680.pdf). Provide copies of the card to personnel when they sign the required receipt of safety information form before each use of the range.
9. Implement and enforce a policy where all persons entering the range area wear no-slip style disposable shoe covers. Figure 1 shows suggested locations for shoe cover supply and disposal.
    a. Maintain a supply of shoe covers at the entrance to the range area so that shoe covers can be put on just after entering the range area from the hallway in the main building.
    b. Provide a shoe cover disposal bin on the range side of the exit door to the weapons cleaning area. Shooters can remove shoe covers before stepping onto the adhesive mat while passing through the door to the weapons cleaning area.
    c. Maintain a second shoe cover supply on the weapons cleaning area side of the exit door. Shoe covers can be put on after exiting the range area before moving around the weapons cleaning area.
    d. Provide a second shoe cover disposal bin at the outer door to the range area so that shoe covers can be disposed of just before exiting the range area into the main building.
    e. Make sure that all shoe cover disposal bins have lids that close.
10. Encourage the safety officer to provide frequent reminders to instructors engaging in daily range cleaning activities on the proper methods to use (e.g., wet cleaning and high efficiency particulate air filtered vacuuming).
11. Begin keeping OSHA Form 300, Log of Work-Related Injuries and Illnesses.
12. Consult a certified industrial hygienist to repeat air and surface wipe sampling after implementing changes to evaluate their efficacy in reducing lead exposure.
13. Encourage instructors to talk to their healthcare provider about their exposure to lead and about the possibility of take-home contamination with lead. Encourage instructors to have family members and other individuals who live with instructors or regularly ride in their vehicles to get their BLLs tested.
14. Ensure personnel and contractors doing range maintenance, changing ventilation system air filters, and scraping the bullet trap are compliant with the OSHA lead standard [29 CFR 1910.1025].

Personal Protective Equipment

Personal protective equipment is the least effective means for controlling hazardous exposures. Proper use of personal protective equipment requires a comprehensive program and a high level of employee involvement and commitment. The right personal protective equipment must be chosen for each hazard. Supporting programs such as training, change-out schedules, and medical assessment may be needed. Personal protective equipment should not be the sole method for controlling hazardous exposures. Rather, personal protective equipment should be used until effective engineering and administrative controls are in place.

1. Encourage the use of disposable nitrile gloves by shooters while cleaning their weapons and during range cleanup activities. Do not use natural rubber latex gloves because they can result in allergic reactions for some people.
2. Instruct shooters and instructors to wear disposable nitrile gloves whenever handling the broken target retrieval system. This includes pushing and pulling the target while downrange as well as changing the targets.
3. Wear and change no-slip style disposable shoe covers according to the new policy described under Administrative Controls.

Appendix A: Diagram of the Firing Range

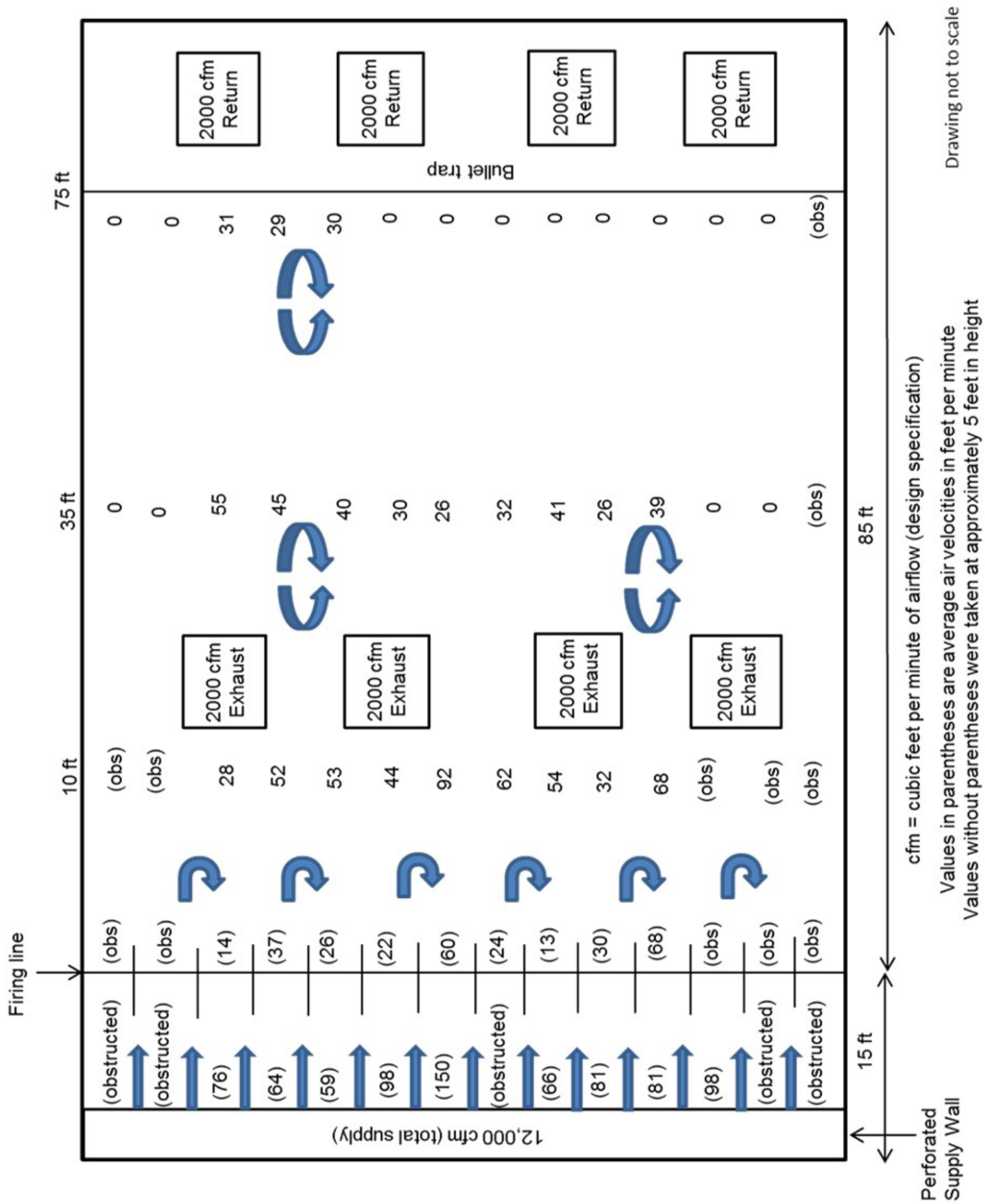

Figure A1. Range diagram showing air velocities at different locations on the range and the locations of supply and exhaust registers. The arrows show the direction of airflow that was visualized with the smoke machine.

Appendix B: Occupational Exposure Limits and Health Effects of Lead

NIOSH investigators refer to mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a pre-existing medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended STEL or ceiling values. Unless otherwise noted, the STEL is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits. These limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH RELs are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2010]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Another set of OELs commonly used and cited in the United States is the ACGIH TLVs. The TLVs are developed by committee members of this professional organization from a review of the published, peer-reviewed literature. TLVs are not consensus standards. They are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2017].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen

Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at http://www.dguv.de/ifa/GESTIS/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 2,000 hazardous substances and is updated periodically.

OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions. NIOSH investigators also encourage use of the hierarchy of controls approach to eliminate or minimize workplace hazards. This includes, in order of preference, the use of (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health. Control banding focuses on how broad categories of risk should be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement existing OELs.

Background on Lead

Inorganic lead is a naturally occurring, soft metal that has been mined and used in industry since ancient times. It comes in many forms (e.g., lead acetate, lead chloride, lead chromate, lead nitrate, lead oxide, lead phosphate, and lead sulfate). Lead is considered toxic to all organ systems and serves no useful purpose in the body.

Occupational exposure to inorganic lead occurs via inhalation of lead-containing dust and fume and ingestion of lead particles from contact with lead-contaminated surfaces. Exposure may also occur through transfer of lead to the mouth from contaminated hands or cigarettes when careful attention to hygiene, particularly hand washing, is not practiced. In addition to the inhalation and ingestion routes of exposure, lead can be absorbed through the skin, particularly through damaged skin [Filon et al. 2006; Stauber et al. 1994; Sun et al. 2002].

Workplace settings with exposure to lead and lead compounds include smelting and refining, scrap metal recovery, automobile radiator repair, construction and demolition (including abrasive blasting), and firing ranges [Koh et al. 2015]. Lead exposure and resultant elevated BLLs in those who use and staff firing ranges have been well described in the literature and in previous NIOSH health hazard evaluations [Institute of Medicine 2012; Laidlaw et al. 2017; NIOSH 2013, 2014]. Occupational exposures also occur among workers who apply or remove lead-based paint and among welders who burn or torch-cut metal structures.

Blood Lead Levels

In most cases, an individual's BLL is a good indication of recent exposure to lead because the half-life of lead (the time interval it takes for the quantity in the body to be reduced by half its initial value) is 1–2 months [Centers for Disease Control and Prevention 2013a; Lauwerys and Hoet 2001; Moline and Landrigan 2005]. Most lead in the body is stored in the bones, with a half-life of years to decades. Measuring bone lead, however, is primarily done only for research. Elevated zinc protoporphyrin levels have also been used as an indicator of chronic lead intoxication. However, other factors, such as iron deficiency, can cause an elevated zinc protoporphyrin level, so monitoring the BLL over time is more specific for evaluating chronic occupational lead exposure.

BLLs in adults in the United States have declined consistently over time. The geometric mean BLL went from 1.75 µg/dL in 1999–2000 to 1.09 µg/dL in 2011–2012 [Centers for Disease Control and Prevention 2015b]. The NIOSH Adult Blood Lead Epidemiology and Surveillance System uses a surveillance case definition for an elevated BLL in adults of 5 µg/dL of blood or higher [Centers for Disease Control and Prevention 2015a]. Very high BLLs are defined as BLLs ≥ 40 µg/dL. From 2002–2011, occupational exposures accounted for 91% of adults with very high BLLs (where exposure source was known) [Centers for Disease Control and Prevention 2013b]. This underscores the need to increase efforts to prevent lead exposures in the workplace. Recent compilations of BLLs in employees obtained during an HHE at a firing range along with surveillance data from Washington state showed increased BLLs in not just the range employees but their family members as well [Centers for Disease Control and Prevention 2014].

Occupational Exposure Limits

In the United States, employers in general industry are required by law to follow the OSHA lead standard (29 CFR 1910.1025). This standard was established in 1978 and has not yet been updated to reflect the current scientific knowledge regarding the health effects of lead exposure.

Under this standard, the PEL for airborne exposure to lead is 50 µg/m^3 of air for an 8-hour TWA. The standard requires lowering the PEL for shifts that exceed 8 hours, medical monitoring for employees exposed to airborne lead at or above the action level of 30 µg/m^3 (8-hour TWA), medical removal of employees whose average BLL is 50 µg/dL or greater, and economic protection for medically removed workers. Medically removed workers cannot return to jobs involving lead exposure until their BLL is below 40 µg/dL.

In the United States, other guidelines for lead exposure, which are not legally enforceable, are often followed. Similar to the OSHA lead standard, these guidelines were set years ago and have not yet been updated to reflect current scientific knowledge. NIOSH has a REL for lead of 50 µg/m^3 averaged over an 8-hour work shift [NIOSH 2010]. ACGIH has a TLV for lead of 50 µg/m^3 (8-hour TWA), with worker BLLs to be controlled to, or below, 20 µg/dL. ACGIH designates lead as an animal carcinogen [ACGIH 2017]. In 2013, the California Department of Public Health recommended that California OSHA lower the PEL for lead to 0.5 to 2.1 µg/m^3 (8-hour TWA) to keep BLLs below the range of 5 to 10 µg/dL [Billingsley 2013].

Neither NIOSH nor OSHA has established surface contamination limits for lead in the workplace. The U.S. Environmental Protection Agency and the U.S. Department of Housing and Urban Development limit lead on surfaces in public buildings and child-occupied housing to less than 40 micrograms of lead per square foot [EPA 1998; HUD 2012]. OSHA requires in its substance-specific standard for lead that all surfaces be maintained as free as practicable of accumulations of lead [29 CFR 1910.1025(h)(1)]. An employer with workplace exposures to lead must implement regular and effective cleaning of surfaces in areas such as change areas, storage facilities, and lunchroom/eating areas to ensure they are as free as practicable from lead contamination.

Health Effects

The OSHA PEL, NIOSH REL, and ACGIH TLV may prevent overt symptoms of lead poisoning, but do not protect workers from lead's contributions to conditions such as hypertension, renal dysfunction, or reproductive and cognitive effects [Brown-Williams et al. 2009; Holland and Cawthorn 2016; Institute of Medicine 2012; Schwartz and Hu 2007; Schwartz and Stewart 2007]. Generally, acute lead poisoning with symptoms has been documented in persons having BLLs above 70 µg/dL. These BLLs are rare today in the United States, largely as a result of workplace controls put in place to comply with current OELs. When present, acute lead poisoning can cause myriad adverse health effects including abdominal pain, hemolytic anemia, and neuropathy. Lead poisoning has, in very rare cases, progressed to encephalopathy and coma [Moline and Landrigan 2005].

People with chronic lead poisoning, which is more likely at current occupational exposure levels, may not have symptoms or they may have nonspecific symptoms that may not be recognized as being associated with lead exposure. These symptoms include headache, joint and muscle aches, weakness, fatigue, irritability, depression, constipation, anorexia, and abdominal discomfort [Moline and Landrigan 2005].

The National Toxicology Program released a monograph on the health effects of low-level lead exposure [NTP 2012]. For adults, the National Toxicology Program concluded the following about the evidence regarding health effects of lead (Table B1).

Table B1. Evidence regarding health effects of lead in adults

Health area	NTP conclusion	Principal health effects	Blood lead evidence
Neurological	Sufficient	Increased incidence of essential tremor	Yes, < 10 µg/dL
	Limited	Psychiatric effects, decreased hearing, decreased cognitive function, increased incidence of amyotrophic lateral sclerosis	Yes, < 10 µg/dL
	Limited	Increased incidence of essential tremor	Yes, < 5 µg/dL
Immune	Inadequate		Unclear
Cardiovascular	Sufficient	Increased blood pressure and increased risk of hypertension	Yes, < 10 µg/dL
	Limited	Increased cardiovascular-related mortality and electrocardiography abnormalities	Yes, < 10 µg/dL
Renal	Sufficient	Decreased glomerular filtration rate	Yes, < 5 µg/dL
Reproductive	Sufficient	Women: reduced fetal growth	Yes, < 5 µg/dL
	Sufficient	Men: adverse changes in sperm parameters and increased time to pregnancy	Yes, ≥ 15–20 µg/dL
	Limited	Women: increase in spontaneous abortion and preterm birth	Yes, < 10 µg/dL
	Limited	Men: decreased fertility	Yes, ≥ 10 µg/dL
	Limited	Men: spontaneous abortion	Yes, ≥ 31 µg/dL
	Inadequate	Women and men: stillbirth, endocrine effects, birth defects	Unclear

Various organizations have assessed the relationship between lead exposure and cancer. According to the Agency for Toxic Substances and Disease Registry [ATSDR 2007] and the National Toxicology Program [NTP 2011], inorganic lead compounds are reasonably anticipated to cause cancer in humans. The International Agency for Research on Cancer classifies inorganic lead as probably carcinogenic to humans [WHO 2006]. According to the American Cancer Society [ACS 2011], some studies show a relationship between lead exposure and lung cancer, but these results might be affected by exposure to cigarette smoking and arsenic. Some studies show a relationship between lead and stomach cancer, and these findings are less likely to be affected by the other exposures. The results of studies looking at other cancers, including brain, kidney, bladder, colon, and rectum, are mixed. In 2015, NIOSH designated 5 µg/dL of whole blood, in a venous blood sample, as the reference BLL for adults. This definition created for surveillance purposes, defined an elevated BLL is defined as a BLL ≥ 5 µg/dL [NIOSH 2015].

Medical Management

To prevent acute and chronic health effects, a panel of experts convened by the Association of Occupational and Environmental Clinics published guidelines for the management of adult lead exposure [Kosnett et al. 2007]. The panel recommended BLL testing for all lead-exposed employees, regardless of the airborne lead concentration. These recommendations do not apply to pregnant women, who should avoid BLLs > 5 µg/dL. Removal from lead exposure should be considered if control measures over an extended period do not decrease BLLs to < 10 µg/dL or an employee has a medical condition that would increase the risk of adverse health effects from lead exposure. These guidelines were endorsed by the Council of State and Territorial Epidemiologists and the California Department of Public Health in 2009 and the American College of Occupational and Environmental Medicine in 2010 [ACOEM 2010; CDPH 2009; CSTE 2009]. The Council of State and Territorial Epidemiologists published updated guidelines in 2013 to reflect the new definition of an elevated BLL in adults of 5 µg/dL [CSTE 2013]. The California Department of Public Health recommended keeping BLLs below 5 to 10 µg/dL in 2013 [Billingsley 2013] and updated its medical management guidelines in 2014 [CDPH 2014]. In 2016, the American College of Occupational and Environmental Medicine released a position statement entitled "Workplace Lead Exposure," which reinforces the guidelines and recommendations above [Holland and Cawthorn 2016]. Table B2 incorporates recommendations from the expert panel guidelines and those from the California Department of Public Health, American College of Occupational and Environmental Medicine, and the Council of State and Territorial Epidemiologists.

Take-home Contamination

Occupational exposures to lead can result in exposures to household members, including children, from take-home contamination. Take-home contamination occurs when lead dust is transferred from the workplace on employees' skin, clothing, shoes, and other personal items to their vehicle and home [Centers for Disease Control and Prevention 2009, 2012].

The Centers for Disease Control and Prevention considers a BLL in children of 5 µg/dL or higher as a reference level above which public health actions should be initiated and states that no safe BLL in children has been identified [Centers for Disease Control and Prevention 2013a].

The U.S. Congress passed the Workers' Family Protection Act in 1992 (29 U.S.C. 671a). The Act required NIOSH to study take-home contamination from workplace chemicals and substances, including lead. NIOSH found that take-home exposure is a widespread problem [NIOSH 1995]. Workplace measures effective in preventing take-home exposures were (1) reducing exposure in the workplace, (2) changing clothes before going home and leaving soiled clothing at work for laundering, (3) storing street clothes in areas separate from work clothes, (4) showering before leaving work, and (5) prohibiting removal of toxic substances or contaminated items from the workplace. NIOSH noted that preventing take-home exposure is critical because decontaminating homes and vehicles is not always effective. Normal house cleaning and laundry methods are inadequate, and decontamination can expose the people doing the cleaning and laundry.

Table B2. Health-based medical surveillance recommendations for lead-exposed employees

Category of exposure	Recommendations
All lead exposed workers	• Baseline or preplacement medical history and physical examination, baseline BLL, and serum creatinine
BLL < 5 µg/dL	• BLL monthly for first 3 months placement, or upon change in task to higher exposure, then BLL every 6 months; if BLL increases ≥ 5 µg/dL, evaluate exposure and protective measures, and increase monitoring if indicated
BLL 5–9 µg/dL	• Discuss health risks • Minimize exposure • Consider removal for pregnancy and certain medical conditions • BLL monthly for first 3 months placement or every 2 months for the first 6 months placement, or upon change in task to higher exposure, then BLL every 6 months; if BLL increases ≥ 5 µg/dL, evaluate exposure and protective measures, and increase monitoring if indicated
BLL 10–19 µg/dL	• Discuss health risks • Decrease exposure • Remove from exposure for pregnancy • Consider removal for certain medical conditions or BLL ≥ 10 µg/dL for extended period • BLL every 3 months; evaluate exposure, engineering controls, and work practices; consider removal. • Revert to BLL every 6 months after 3 BLLs < 10 µg/dL
BLL 20–29 µg/dL	• Remove from exposure for pregnancy • Remove from exposure if repeat BLL measured in 4 weeks remains ≥ 20 µg/dL • Annual lead medical exam recommended • Monthly BLL testing • Consider return to work after 2 BLLs < 15 µg/dL a month apart, then monitor as above
BLL 30–49 µg/dL	• Remove from exposure • Prompt medical evaluation • Monthly BLL testing • Consider return to work after 2 BLLs < 15 µg/dL a month apart, then monitor as above
BLL 50–79 µg/dL	• Remove from exposure • Prompt medical evaluation • Consider chelation with significant symptoms
BLL ≥ 80 µg/dL	• Remove from exposure • Urgent medical evaluation • Chelation may be indicated

Adapted from Kosnett et al. 2007, CSTE 2013, and CDPH 2014.

Appendix C: Portable Blood Lead Testing Device

The gold standard for BLL measurement is collection of a venous sample, which is analyzed in a laboratory. This method can be costly and does not provide an instantaneous result. Measuring lead in the workplace has been suggested, but interference from skin contamination with lead in the workplace has been a concern [Taylor et al. 2001]. To learn whether skin contamination concerns could be addressed, NIOSH researchers have assessed the effectiveness of cleansing methods. In one study, the traditional soap and water method for hand washing did not efficiently remove lead from skin [Filon et al. 2006]. In another, hand washing with a wipe that contains a pH balanced wetting agent and chelating agent was greater than 99% effective in removing lead from skin [Esswein et al. 2011]. This technology is available commercially.

NIOSH researchers have an ongoing study at several workplaces to compare the BLLs from finger capillary samples that are analyzed by the LeadCare II® to venous BLLs analyzed at a reference laboratory and to compare the BLLs from finger capillary samples taken from a finger cleaned with soap and water to those of a finger cleaned with Hygenall®. As part of this project, we evaluated the LeadCare II® Test Kit, which measures lead in fresh whole blood from either a skin puncture or a venipuncture. We asked instructors who were having their blood collected for lead to allow us to collect a capillary blood sample from one finger on each hand. Prior to sample collection, one hand was cleaned with a PDI® castile soap towelette and rinsed with water, and the other was cleaned with a Hygenall (a lead removal soap) hand wipe and rinsed with water.

Each instructor's capillary blood sample results from the Test Kit were compared to the results of their venous BLL testing reported by our contract laboratory. For statistical analysis, we used the student's paired t-test and Pearson's correlation coefficient (the r value) to compare results for the two methods (Excel Microsoft Office 2013). Results with P values ≤ 0.05 were considered statistically significant. The LeadCare II instrument has a limit of detection (LOD) of 3.3 µg/dL. Two of the four venous samples analyzed by the Test Kit reported as less than the LOD. None of the capillary samples returned results less than the limit of detection. The contract laboratory's LOD for venous BLL is 0.50 µg/dL and none of the samples were below it.

All four instructors participated in the research component. The mean venous BLL for all four instructors as analyzed by the contract lab was 7.0 µg/dL. The mean venous BLL for all four instructors analyzed by the Test Kit was 9.5 µg/dL for the venous blood sample, 7.7 µg/dL for the capillary blood sample drawn after the skin was cleaned by the lead removal soap wipe, and 7.25 µg/dL for the capillary blood sample drawn after the skin was cleaned with the castile soap. The mean capillary BLLs for the hand cleaned with the castile soap towelette were not statistically different from the mean venous BLL obtained from the contract laboratory ($P = 0.59$); similarly, the mean capillary BLLs for the hand cleaned with the lead removal soap wipe were not statistically different from the mean venous BLL obtained from the contract laboratory ($P = 0.57$).

This data will be pooled with data obtained using this research protocol in conjunction with other HHEs to see if the larger dataset would support use of the Test Kit for capillary blood samples in the field. The results we found with this limited sample set are consistent with previous results showing that venous blood tested with the Test Kit and venous blood tested in the laboratory had a mean difference of 1.2 µg/dL, which is clinically insignificant [Stanton and Fritsch 2007].

In May 2017, the U.S. Food and Drug Administration (FDA) issued a recall of all the LeadCare Testing Systems produced by Magellan due to concerns regarding its use in analyzing venous blood specimens. This recall included the Magellan Lead Care II unit that was used in our evaluation. The recall was due to the unit reporting falsely low results when analyzing venous blood specimens even though it still appeared to be accurate when analyzing fingerstick blood samples. The cause of this issue is currently being investigated by the company and the Centers for Disease Control and Prevention [FDA 2017].

References

ACGIH [2017]. 2017 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACOEM [2010]. ACOEM provides input to OSHA on key issues facing agency in 2010. Letter to David Michaels. Elk Grove Village, IL: American College of Occupational and Environmental Medicine, http://www.acoem.org/Page2Column.aspx?PageID=7392&id=6676.

ACS [2011]. Lead. Atlanta, GA: American Cancer Society, http://www.cancer.org/cancer/cancercauses/othercarcinogens/athome/lead.

ATSDR [2007]. Toxicological profile for lead. Atlanta, GA: U.S. Department of Health and Human Services.

Billingsley KJ [2013]. Letter of September 30, 2013, from K.J. Billingsley, California Department of Public Health, to Juliann Sum, Division of Occupational Safety and Health (Cal/OSHA), California Department of Industrial Relations.

Brown-Williams H, Lichterman J, Kosnett M [2009]. Indecent exposure: lead puts workers and families at risk. Health Research for Action, University of California, Berkeley. Perspectives *4*(1):1–9, http://www.healthresearchforaction.org/sites/default/files/PDF_PERSPECTIVES_IndecentExp%20FNL_0.pdf.

Centers for Disease Control and Prevention [2009]. Childhood lead poisoning associated with lead dust contamination of family vehicles and child safety seats --- Maine, 2008. MMWR *58*(32):890–893.

Centers for Disease Control and Prevention [2012]. Take-home lead exposure among children with relatives employed at a battery recycling facility – Puerto Rico, 2011. MMWR *61*(47):967–970.

Centers for Disease Control and Prevention [2013a]. Blood lead levels in children aged 1–5 years — United States, 1999–2010. MMWR *62*(13):245–248.

Centers for Disease Control and Prevention [2013b]. Very high blood lead levels among adults — United States, 2002–2011. MMWR *62*(47):967–971.

Centers for Disease Control and Prevention [2014]. Indoor firing ranges and elevated blood lead levels — United States, 2002–2013. MMWR *63*(16):347–351.

Centers for Disease Control and Prevention [2015a]. Adult blood lead epidemiology and surveillance (ABLES), http://www.cdc.gov/niosh/topics/ables/description.html.

Centers for Disease Control and Prevention [2015b]. Fourth national report on human exposure to environmental chemicals updated tables, February, 2015, http://www.cdc.gov/biomonitoring/pdf/FourthReport_UpdatedTables_Feb2015.pdf.

CDPH [2009]. Medical guidelines for the lead-exposed worker. Sacramento, CA: California Department of Public Health, Occupational Lead Poisoning Prevention Program, http://www.cdph.ca.gov/programs/olppp/Documents/medgdln.pdf.

CDPH [2014]. Management guidelines for blood lead levels in adults. Sacramento, CA: California Department of Public Health, Occupational Lead Poisoning Prevention Program, http://www.cdph.ca.gov/programs/olppp/documents/adultmgtguide.pdf.

CFR. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

CSTE [2009]. Public health reporting and national notification for elevated blood lead levels. CSTE position statement 09-OH-02. Atlanta, GA: Council of State and Territorial Epidemiologists, http://c.ymcdn.com/sites/www.cste.org/resource/resmgr/PS/09-OH-02.pdf.

CSTE [2013]. Management guidelines for blood lead levels in adults. Atlanta, GA: Council of State and Territorial Epidemiologists, http://c.ymcdn.com/sites/www.cste.org/resource/resmgr/OccupationalHealth/ManagementGuidelinesforAdult.pdf.

CSTE [2015]. Public health reporting and national notification for elevated blood lead levels. CSTE position statement 15-eH-01. Atlanta, GA: Council of State and Territorial Epidemiologists, http://c.ymcdn.com/sites/www.cste.org/resource/resmgr/2015PS/2015PSFinal/15-EH-01.pdf.

EPA [1996]. EPA and HUD move to protect children from lead-based paint poisoning; discloser of lead-based paint hazards in housing. Environmental Protection Agency Publication EPA-747-F-96-002. Washington, DC, https://www.epa.gov/sites/production/files/documents/fs-discl.pdf.

EPA [1998]. Risk analysis to support standards for lead in paint, dust, and soil. Environmental Protection Agency Publication EPA-747-R097-006. Washington, DC, http://www2.epa.gov/lead/risk-analysis-support-standards-lead-paint-dust-and-soil-volume-i-chapters-1-7-and-appendix-epa.

Esswein EJ, Boeniger MF, Ashley K [2011]. Handwipe method for removing lead from skin. J ASTM Int 8(5):JAI103527 In: Source surface and dermal sampling. Brisson M, Ashley K, eds., West Conshohocken, PA: ASTM International, STP 1533, pp. 57–66, https://doi.org/10.1520/stp49744s.

FDA [2017]. FDA warns against using magellan diagnostics LeadCare testing systems with blood obtained from a vein: FDA safety communication, https://www.fda.gov/MedicalDevices/Safety/AlertsandNotices/ucm558733.htm.

Filon FL, Boeniger M, Maina G, Adami G, Spinelli P, Damian A [2006]. Skin absorption of inorganic lead (PbO) and the effect of skin cleansers. J Occup Environ Med *48*(7):692–699, https://doi.org/10.1097/01.jom.0000214474.61563.1c.

FLETC [2015]. Firearms instructor training program course description, https://www.fletc.gov/training-program/firearms-instructor-training-program.

Holland MG, Cawthorn D [2016]. ACOEM position statement: workplace lead exposure. JOEM *58*(12):371–373, https://doi.org/10.1097/jom.0000000000000928.

HUD [2012]. Guidelines for the evaluation and control of lead-based paint hazards in housing, http://portal.hud.gov/hudportal/HUD?src=/program_offices/healthy_homes/lbp/hudguidelines.

Institute of Medicine [2012]. Potential health risks from recurrent lead exposure of DOD firing range personnel. Washington, DC: National Academies Press, https://www.ncbi.nlm.nih.gov/books/NBK206966/pdf/Bookshelf_NBK206966.pdf.

Koh DH, Locke SJ, Chen YC, Purdue MP, Friesen MC [2015]. Lead exposure in US worksites: a literature review and development of an occupational lead exposure database from the published literature. Am J Ind Med *58*(6):605–616, http://dx.doi.org/10.1002/ajim.22448.

Kosnett MJ, Wedeen RP, Rothenberg SJ, Hipkins KL, Materna BL, Schwartz BS, Hu H, Woolf A [2007]. Recommendations for medical management of adult blood lead exposure. Environ Health Perspect *115*(3):463–471, https://doi.org/10.1289/ehp.9784.

Laidlaw MAS, Filippelli G, Mielke H, Gulson B, Ball AS [2017]. Lead exposures and firing ranges–a review. Environ Health *16*(34):1–15, https://doi.org/10.1186/s12940-017-0246-0.

Lauwerys RR, Hoet P [2001]. Industrial chemical exposure: guidelines for biological monitoring. 3rd ed. Boca Raton, FL: CRC Press, LLC, pp. 21–180.

Moline JM, Landrigan PJ [2005]. Lead. In: Rosenstock L, Cullen MR, Brodkin CA, Redlich CA, eds. Textbook of clinical occupational and environmental medicine. 2nd ed. Philadelphia, PA: Elsevier Saunders, pp. 967–979.

NIOSH [1995]. Report to Congress on the workers' home contamination study conducted under the Workers' Family Protection Act 29 U.S.C. 671a. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 95-123, http://www.cdc.gov/niosh/docs/95-123/.

NIOSH [2001]. Issues related to occupational exposures to lead 1994 to 1999. By Reh BD. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2001-113, https://www.cdc.gov/niosh/docs/2001-113/pdfs/2001-113.pdf.

NIOSH [2009]. Preventing occupational exposures to lead and noise at indoor firing ranges. By Kardous CA, King BF, Khan A, Whelan EA, Tubbs RL, Barsan ME, Crouch KG, Murphy WJ, Willson RD, Esswein EJ, Boeniger MF. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2009-136, https://www.cdc.gov/niosh/docs/2009-136/pdfs/2009-136.pdf.

NIOSH [2010]. NIOSH pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2010-168c, http://www.cdc.gov/niosh/npg/.

NIOSH [2013]. Followback evaluation of lead and noise exposures at an indoor firing range. By Ramsey JG, Niemeier RN, Page E, Chen L, Choi J. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2012-0065-3195, https://www.cdc.gov/niosh/hhe/reports/pdfs/2012-0065-3195.pdf.

NIOSH [2014]. Lead exposures at a firing range and gun store. By Page E, Beaucham C, Methner M. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2013-0119-3219, https://www.cdc.gov/niosh/hhe/reports/pdfs/2013-0119-3219.pdf.

NIOSH [2015]. Adult Blood Lead Epidemiology & Surveillance (ABLES). https://www.cdc.gov/niosh/topics/ables/description.html, Page Last Updated December 22, 2015.

NIOSH [2017]. NIOSH manual of analytical methods (NMAM). 5th ed. O'Connor PF, Ashley K, eds. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2014-151, http://www.cdc.gov/niosh/nmam.

NTP [2011]. Report on carcinogens, 12th ed. Research Triangle Park, NC: U.S. Department of Health and Human Services, National Institutes of Health, National Institute of Environmental Health Sciences, National Toxicology Program, http://ntp.niehs.nih.gov/ntp/roc/twelfth/profiles/Lead.pdf.

NTP [2012]. Monograph on the health effects of low-level lead. Research Triangle Park, NC: U.S. Department of Health and Human Services, National Institutes of Health, National Institute of Environmental Health Sciences, National Toxicology Program, https://ntp.niehs.nih.gov/ntp/ohat/lead/final/monographhealtheffectslowlevellead_newissn_508.pdf.

Schwartz BS, Hu H [2007]. Adult lead exposure: time for change. Environ Health Perspect *115*(3):451–454, https://doi.org/10.1289/ehp.9782.

Schwartz BS, Stewart WF [2007]. Lead and cognitive function in adults: a question and answers approach to a review of the evidence for cause, treatment, and prevention. Int Rev Psychiatry *19*(6):671–692, https://doi.org/10.1080/09540260701797936.

Stanton NV, Fritsch T [2007]. Evaluation of a second-generation portable blood lead analyzer in an occupational setting. Am J Ind Med *50*(12):1018–1024, https://doi.org/10.1002/ajim.20525.

Stauber JL, Florence TM, Gulson B, Dale L [1994]. Percutaneous absorption of inorganic lead compounds. Sci Total Environ *145*(1–2):55–70, https://doi.org/10.1016/0048-9697(94)90297-6.

Sun CC, Wong TT, Hwang YH, Chao KY, Jee SH, Wang JD [2002]. Percutaneous absorption of inorganic lead compounds. Am Ind Hyg Assoc J *63*(5):641–646, https://doi.org/10.1080/15428110208984751.

Taylor L, Jones RL, Kwan L, Deddens JA, Ashley K, Sanderson WT [2001]. Evaluation of a portable blood lead analyzer with occupationally exposed populations. Am J Ind Med *40*(4):354–362, https://doi.org/10.1002/ajim.1109.

WHO [2006]. IARC monographs on the evaluation of carcinogenic risks to humans volume 87. Inorganic and organic lead compounds. Summary of data reported and evaluation. World Health Organization, Geneva, Switzerland, http://monographs.iarc.fr/ENG/Monographs/vol87/.

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Copies of this report have been sent to the employer and employees at the facility. The state and local health department and the Occupational Safety and Health Administration Regional Office have also received a copy.

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